# Ordovician–Silurian boundary in Victoria and New South Wales, Australia


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## Synopsis

The late Ordovician and early Silurian is often represented by an unconformity or otherwise by beds bearing graptolites: no significant shelly faunas are known. In Darraweit Guim, Victoria, and in the Forbes–Parkes area of New South Wales, there may be beds spanning the Ordovician–Silurian boundary without a break, but nowhere have both the *persculptus* and *acuminatus* Zones been found in a single, structurally uncomplicated, succession.


## Introduction

Ordovician and Silurian rocks crop out extensively in the Lachlan Fold Belt of southeastern Australia (Figs 1 and 3). A variety of facies is represented, from deep marine chert, black shale and turbidites, to shallow marine mudstone and sandstone. Carbonates and volcaniclastics occur, associated with island arc-type andesites in central New South Wales. The turbidite—black shale—chert association often contains rich and diverse graptolite assemblages and conodonts, but virtually no shelly fossils. Mixed graptolite–shelly fossil assemblages occur in some of the volcaniclastic deposits, but the shallow marine carbonates only contain shelly fossils.

## Sections in central and eastern Victoria

No single section spanning the Ordovician–Silurian boundary has yet been located in Victoria, although there is reasonably convincing evidence of a complete but fault-disrupted succession at Darraweit Guim, near Melbourne (Fig. 1). Poor exposure and deep weathering, and the scarcity of fossils in the Silurian rocks, are the main difficulties in locating further sections. Another limiting factor is due to the effects of the Benambran Orogeny, a major accretionary event which took place at about the Ordovician–Silurian boundary and produced the Wagga Metamorphic Belt in eastern Victoria (Cooper & Grindley 1982). The orogeny is marked by a prominent facies change, from black shale with or without turbidites, to massive mudstone or quartzite. East of the metamorphic belt, the facies change follows a break in sedimentation, which in some places was accompanied by folding.

No such break in sedimentation occurs in the Melborne Trough in central Victoria, but here the lithological contrast produced by the Benambran Orogeny is such that the boundary interval became the preferred site for strike faulting during the Middle Devonian Tabberabberan orogeny, thus causing considerable complexity in the boundary sections.

### Darraweit Guim

The only apparently complete succession spanning the Ordovician–Silurian boundary in Victoria occurs at Darraweit Guim, a hamlet 46 km NNW of Melbourne (Fig. 1). It is situated near the western margin of the Melbourne Trough, a basin in which there is record of continuous marine sedimentation from early Ordovician to late Early Devonian time (VandenBerg & Wilkinson, *in* Cooper & Grindley 1982). The boundary sequence recognized by VandenBerg *et al.* (1984) consists of three units, the Bolinda Shale, Darraweit Guim Mudstone and Deep Creek Siltstone (Fig. 2).

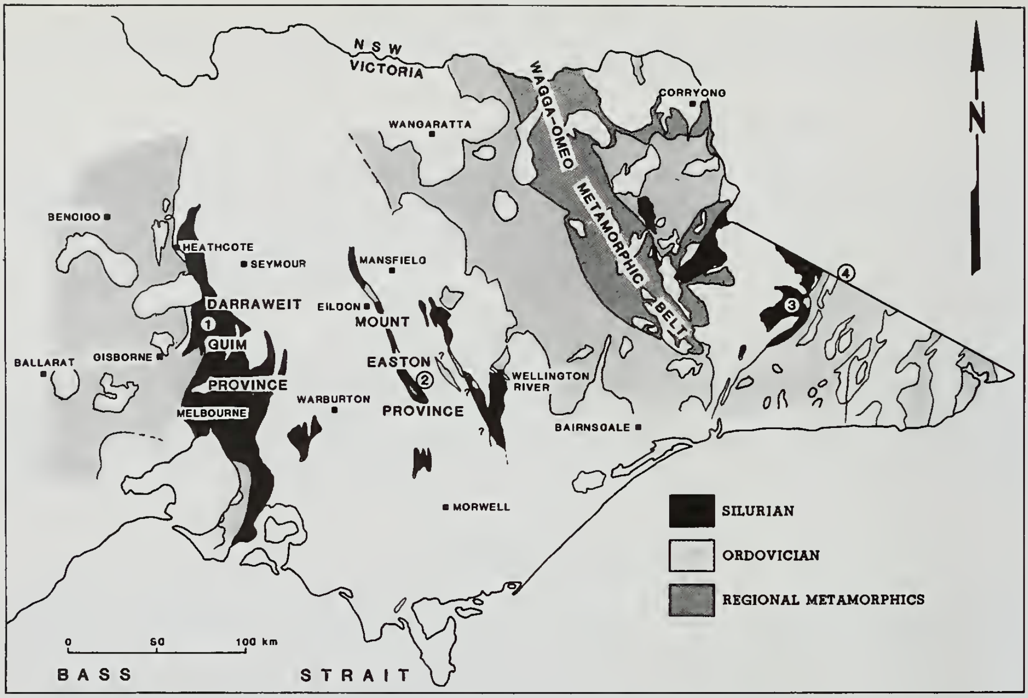


**Fig. 1** Distribution of Ordovician and Silurian rocks in central and eastern Victoria. Localities mentioned in text and Fig. 2 are: 1, Darraweit Guim; 2, Mount Easton region; 3, Yalmy River; 4, Delegate (southeast N.S.W.).

The Bolinda Shale is composed of 800 m or more of thin-bedded coarse-grained black shale and fine sandstone with a rich Bolindian graptolite fauna, comprising mostly cosmopolitan species. The assemblage consists of very abundant *Climacograptus latus*, *C. longispinus supernus* and *Orthograptus amplexicaulis* (sensu lato), somewhat less abundant *C. hastatus*, *C.* cf. *tubuliferus*, *Paraorthograptus pacificus pacificus* and *Dicellograptus ornatus*, and rare specimens of *Orthograptus fastigatus*, *Orthoretiograptus denticulatus* and *Pleurograptus linearis* (sensu lato). This assemblage constitutes the Zone of *D. ornatus* and *C. latus* of VandenBerg (*in* Webby *et al.* 1981) and is virtually identical to that of the *Paraorthograptus pacificus* Subzone at Dob's Linn (Williams 1982).

The overlying Darraweit Guim Mudstone consists of 20 to 45 m of sparsely fossiliferous black calcareous mudstone and slump-folded mudstone of partly evaporitic origin, and may be the only unit in Australia to show the effects of the late Ordovician glaciation (VandenBerg, in prep.). The impoverished shelly fauna consists of small bivalves, hyolithids, straight nautiloids, and a single trilobite, *Songxites darraweitensis*. More important, however, is the occurrence of *Climacograptus*? *extraordinarius* which is associated with *C. angustus* and *C.* cf. *acceptus* (VandenBerg *et al.* 1984). This assemblage represents the upper Bolindian Zone of *C.*? *extraordinarius* and is considered to correlate with the *C.*? *extraordinarius* Zone at Dob's Linn (Williams 1983).

Contacts between the Darraweit Guim Mudstone and the overlying Deep Creek Siltstone are usually poorly exposed and marked by bedding-parallel faults. The Deep Creek Siltstone is very thick (800–1000 m) and consists of poorly bedded, massive and bioturbated siltstone and thin rippled sandstone. Fossils are very rare. The lowest graptolite horizon occurs about 75 m above the base of the formation (and about 90 m above *C.*? *extraordinarius*) and contains *Glyptograptus* sp. (VandenBerg *et al.* 1984: fig. 11). A somewhat richer assemblage occurs 85 m

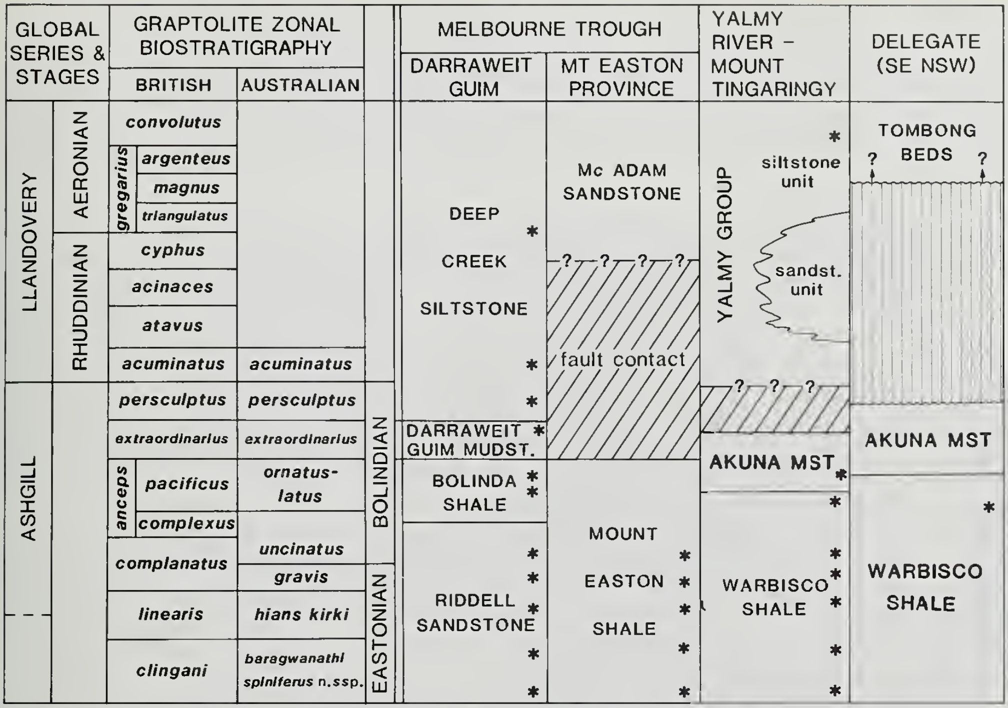


**Fig. 2** Correlation chart of Ordovician–Silurian boundary sections in Victoria. For location of columns, see Fig. 1. Graptolite horizons are shown by asterisks.

and 95 m higher in the same section (VandenBerg *et al.* 1984: fig. 3), and contains *Climacograptus normalis*, *C. angustus*, and *Glyptograptus*? *persculptus* or a species very close to it. This assemblage is considered to correlate with the British *G.*? *persculptus* Zone at Dob's Linn (Williams 1983).

The next graptolite zone, the Zone of *Parakidograptus acuminatus*, is based on a single described specimen of *P. acuminatus* cf. *acuminatus* (VandenBerg *et al.* 1984) which came from the core of an anticline north of Darraweit Guim, low in the Deep Creek Siltstone, but unfortunately structurally isolated from the more complete sections west of Darraweit Guim. Its precise stratigraphical relationship with the *G.*? *persculptus* Zone is therefore not known. The same applies to an assemblage from PL665, low in the Deep Creek Siltstone NW of Darraweit Guim, consisting entirely of *Glyptograptus*? *venustus* (Legrand *non* Mu) (figured as *C. normalis* in VandenBerg *et al.* 1984: fig. 10A).

Little work has been done on the sparse graptolite fauna higher in the Deep Creek Siltstone (Harris & Thomas 1937, 1949), and much of it is in need of revision. Sufficient material has been collected, however, to indicate that the graptolite record is far from complete and can only be correlated with reference to the standard British sequence.

## Mount Easton

In the Mount Easton Province, farther east in the Melborne Trough (Fig. 1), VandenBerg (*in* Webby *et al.* 1981) has recognized a nearly complete Upper Ordovician sequence of graptolite faunas in the Mount Easton Shale (Fig. 2). Faunas range from the Darriwilian Zone of *Pseudoclimacograptus*? *decoratus* to the Bolindian Zone of *Dicellograptus ornatus* and *Climacograptus latus*. VandenBerg (1975) has recorded a possibly conformable relationship with overlying siltstone near Eildon, but elsewhere the shale is in fault contact with the 500 m thick McAdam

Sandstone (VandenBerg 1975). The latter contains a small late Llandovery graptolite assemblage including *Retiolites geinitzianus* (recorded as *Stomatograptus australis*), *Monograptus exiguus*, *M. turriculatus*, *M. spiralis permensus*, *M. priodon* and *M. pandus* (Keble & Harris 1934; Harris & Thomas 1947). There is a single record of Silurian graptolites, listed as *Glyptograptus tamariscus*, *Climacograptus* sp. and *Monograptus* spp. (Harris & Thomas 1954) from an outcrop adjacent to Mount Easton Shale in the structurally complex Mount Wellington Belt.

**Eastern Victoria and the borderland with New South Wales**

In the Yalmy River–Mount Tingaringy district in eastern Victoria (Fig. 1), the Warbisco Shale comprises about 500 m of black shale. This contains a graptolite sequence which is recorded by VandenBerg (1981) as complete from the Gisbornian Zone of *Nemagraptus gracilis*, to the Bolindian *D. ornatus–C. latus* Zone (Fig. 2). Locally, the black shale is overlain by a thin unit of sandstone and siltstone, the Akuna Mudstone, still with a full *D. ornatus–C. latus* zonal assemblage comprising *Dicellograptus ornatus*, *Climacograptus latus*, *C. longispinus supernus*, *C. hastatus*, *Paraorthograptus pacificus* and *Orthoretiograptus denticulatus*. This unit was formerly placed in the Yalmy Group (VandenBerg, *in* Webby *et al.* 1981: 33) but its relationship is not completely clear. In most places, the contact between Warbisco Shale and undoubted Yalmy Group is faulted, and the entire Akuna Mudstone is absent.

The 3700 m thick Yalmy Group consists of about 2700 m of siltstone containing very large lenses of deltaic? sandstone, overlain by about 1000 m of orthoquartzite turbidites (Fig. 2). Several small graptolite assemblages occur high in the siltstone unit, but only one has been studied sufficiently to permit correlation and it comprises *Petalograptus* sp., *Glyptograptus* sp., *Retiolites* cf. *perlatus*, and a variety of monograptids including *M. convolutus* which correlate with the mid-Llandovery *M. convolutus* Zone of Britain.

At Delegate in southeastern New South Wales, to the northeast of the Yalmy River–Mount Tingaringy district (Fig. 1), the 200–300 m thick Akuna Mudstone (R. A. Glen, in prep.) overlies the entire Warbisco Shale (Fig. 2). Most of the latter formation consists of black shale, ranging in age from Gisbornian (with *Climacograptus bicornis bicornis*) to Bolindian (with *C. latus* and *Orthograptus fastigatus*). A prominent facies change from black shale to grey-green siltstone occurs at the boundary with the Akuna Mudstone and may correlate with the transition from Warbisco Shale to Akuna Mudstone farther west. No fossils have been collected from the upper part of the Akuna Mudstone, but there is a good possibility that the unit extends into the Silurian.

The contact between the Akuna Mudstone and the overlying Tombong Beds is a low-angle unconformity, attributable to the Benambran Orogeny which, elsewhere in the same district, marks a period of strong folding (Glen & VandenBerg 1985, 1987). The Tombong Beds are thick and unfossiliferous, but a small graptolite assemblage has been recorded from the overlying Meriangaah Siltstone by Crook *et al.* (1973). They suggest a broad late Llandovery–early Wenlock age, based on the occurrence of *Retiolites geinitzianus angustidens*, '*Monograptus* cf. *auduncus*' (presumably *Monoclimacis adunca*), and *M.* ex gr. *priodon.*

## Sections in central New South Wales

Similarly, in New South Wales no section has yet been demonstrated to exhibit a complete record of beds across the Ordovician–Silurian boundary. The main limiting factors are the poor exposure, the structural complexity and the lack of continuity of richly fossiliferous successions. Even in the tableland areas the topography is generally subdued, and the sequences are often deeply weathered. The effects of the latest Ordovician–early Silurian Benambran Orogeny are noticeable in many areas of New South Wales, as in eastern Victoria. This major event resulted in the closing of the Wagga Marginal Sea, and then of its deformation, metamorphism and plutonism to produce the upraised Wagga Metamorphic Belt (Fig. 3). No proven Silurian deposits are known to occur to the west of the Wagga Metamorphic Belt, and many areas to the east appear to have a less than complete record of deposition through the Ordovician–

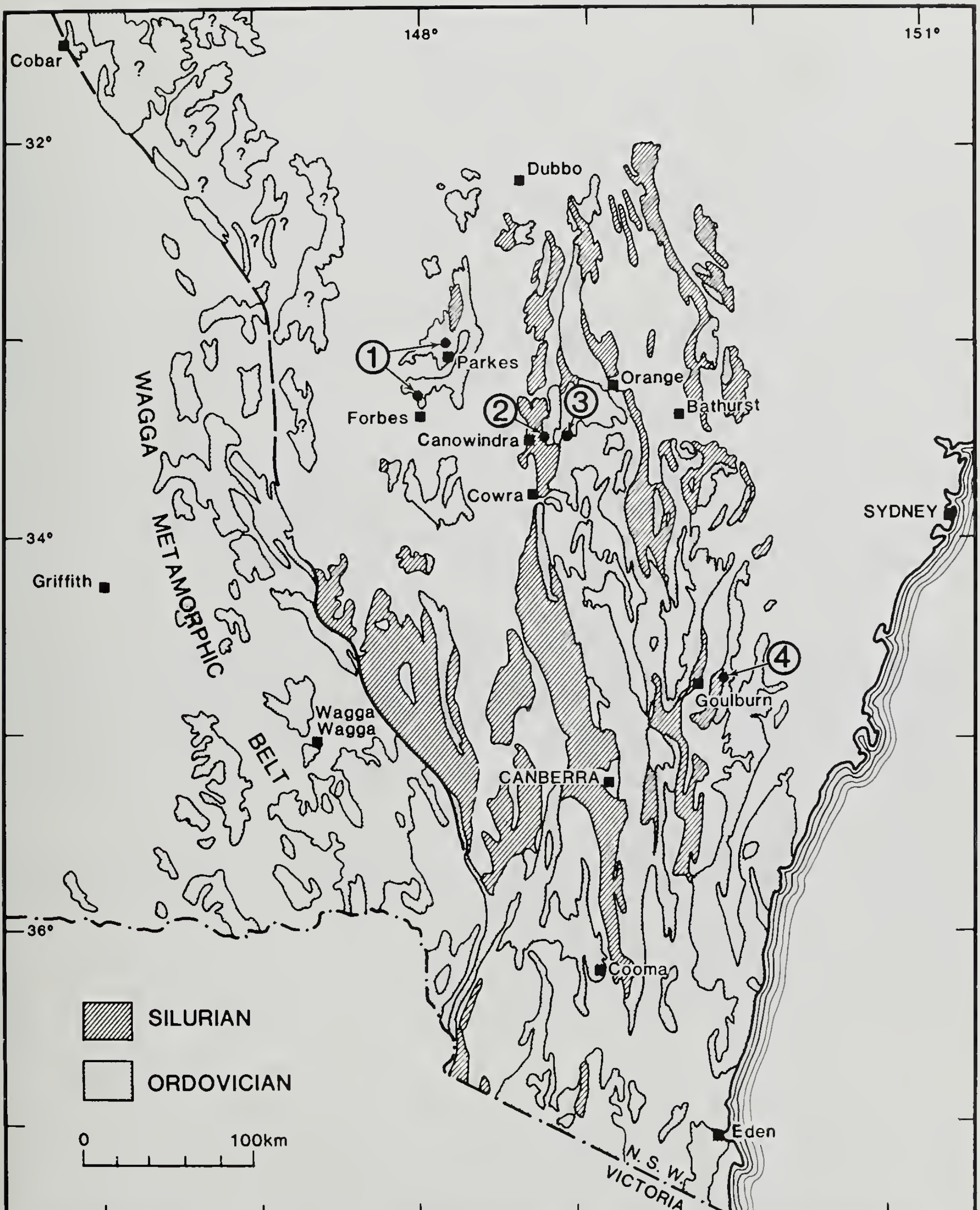


Fig. 3 Map showing the distribution of Ordovician and Silurian rocks in central and southern New South Wales, and the location of Ordovician–Silurian boundary sections represented in Fig. 4.

Silurian boundary interval. The latest Ordovician deposits east of the Wagga Metamorphic Belt accumulated with associated graptolites in deeper waters as did much of the overlying Early Silurian, but many sections show physical breaks (unconformities, disconformities with associated facies changes or faults) reflecting the Benambran orogenesis or subsequent events.

The few sections which appear to show conformity unfortunately have an incomplete record of Late Ordovician to Early Silurian graptolite assemblages—late Bolindian occurrences followed by a significant barren interval to the succeeding mid-Llandovery assemblages, making it impossible to position the boundary closely (Figs 3–4). In addition to the rarity of proven early Llandovery deposits, there is an even greater paucity of established late Bolindian to early Llandovery shelly faunas. Indeed the graptolites are the only group to be adequately represented in the New South Wales successions. The sections with the best potential for establishing the Ordovician–Silurian boundary in New South Wales are in the Forbes area and east of Canowindra. Two less important sections occur in the Angullong–Four Mile Creek area and east of Goulburn.

1. *Forbes–Parkes.* The Cotton Siltstone of the Forbes area comprises separate exposures of a lower unit of late Ordovician age and an upper unit of Early Silurian age (Sherwin 1970, 1973) with an extensive strip of ground in between, representing unexposed intervening beds. Sherwin identified two graptolite assemblages from the lower unit, fauna A characterized by *Climacograptus supernus*, *C. hastatus*, *C. latus*, *Dicellograptus* cf. *elegans* and *Orthograptus truncatus* subsp., and assigned a Bolindian age; and fauna B typified by *C. normalis* and placed by Sherwin at or just above the Ordovician–Silurian boundary. The upper unit contains faunas C and D which are correlated with the late Llandovery (*sedgwickii* and *turriculatus* Zones); see also Sherwin (1974). *C. normalis* is the only determinable graptolite in fauna B and is a long-ranging species, and consequently can be of little use in establishing the position of the

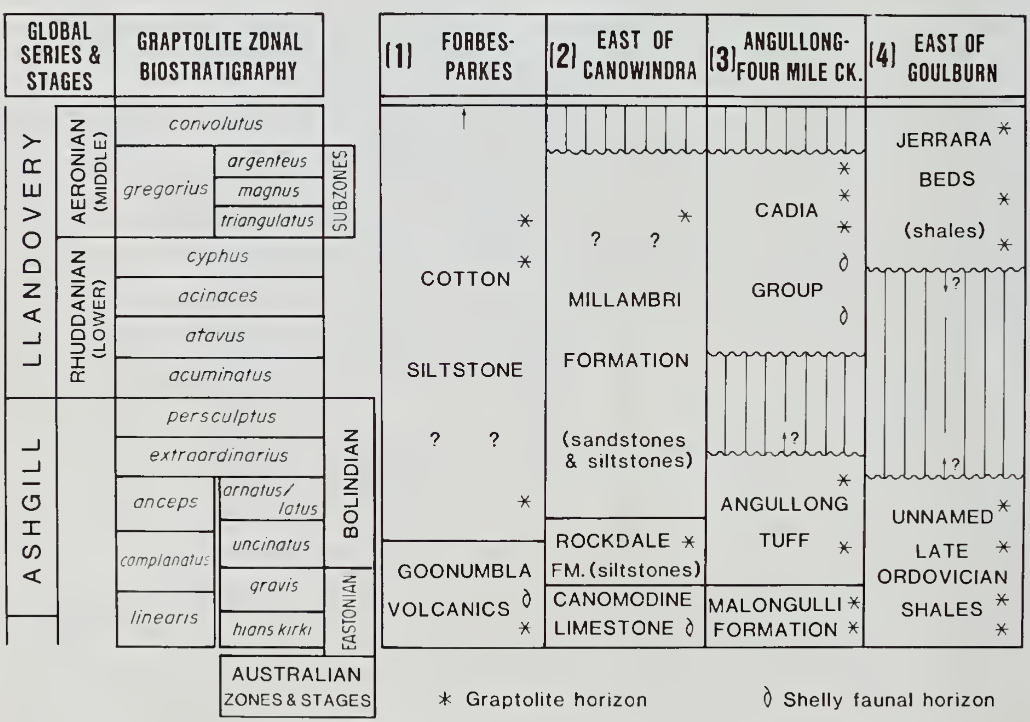


Fig. 4 Correlation chart of Ordovician–Silurian boundary sections in central New South Wales.

boundary. Sherwin (*in* Pickett 1982) estimated the Cotton Siltstone of the Forbes area to be a total of 1500 m thick, and a large part of this is unexposed. For instance, only 100 m of the upper unit is well exposed in the road cutting and quarry near Cotton Trig north-west of Forbes (Sherwin 1973: fig. 4).

At 'The Secrets' north of Parkes, a 90 m thick sequence of the Cotton Siltstone includes several graptolite assemblages (Sherwin 1976) which do not occur near Forbes. These probably come from stratigraphical levels equivalent to the unexposed gap (between faunas B and C) of the Forbes section. The assemblages range in age from late lower to early middle Llandovery (*M. cyphus* to *M. triangulatus* Zones). The earliest assemblages, represented through the interval from 60–70 m on Sherwin's (1976: fig. 3) measured column, include elements such as *Climacograptus normalis*, *Pseudoclimacograptus* sp., *Glyptograptus* sp. and *Monograptus*? *strachani*. Unfortunately, however, there is as yet no evidence in the sections of the Cotton Siltstone near Forbes and Parkes of the presence of either the latest Ordovician graptolite zones of *C.*? *extraordinarius* and *G. persculptus*, or the earliest Llandovery zones of *P. acuminatus* or *C. vesiculosus*. Attempts are to be made to arrange the drilling of the unexposed part of the Forbes section, as it promises to provide the most complete, well preserved and structurally most uncomplicated record of graptolite assemblages through the Ordovician–Silurian boundary interval in Australia.

2. *East of Canowindra*. It is also possible that the Millambri Formation, as redefined by Ryall (1965), contains a continuous sequence of beds across the Ordovician–Silurian boundary but this 1240 m thick siliciclastic (poorly bedded arenite and well bedded siltstone) succession needs to be studied in much more detail. In its type area, in the core of the Cranky Rock Anticline east of Canowindra, Ryall (1965) has recognized the Millambri Formation as resting conformably on the Rockdale Formation. This siltstone unit has a Late Ordovician graptolite assemblage identified by Ryall (1965) as *Climacograptus bicornis* (probably erroneously), *C.* sp., *Dicellograptus* sp. and *Glyptograptus* sp. Judging from its stratigraphical relationships with the underlying Canomodine Limestone, the Rockdale Formation is unlikely to be older than early Bolindian (Webby *et al.* 1981). In a separate faulted sliver at Lidcombe Pools, to the east of the type area, the top of the Millambri Formation has produced a graptolite fauna of middle Llandovery age, that is about the level of the *M. gregarius* Zone. Elements of this fauna have been recorded by Percival (1976) as including *Glyptograptus tamariscus*, *Monograptus jonesi*, *Pseudoclimacograptus* (*Metaclimacograptus*) *hughesi*, *P.* (*M.*) *andulatus* and *P.* (*Clinoclimacograptus*) *retroversus*.

3. *Angullong–Four Mile Creek*. In the Angullong–Four Mile Creek area, Jenkins (1978) has found a late Bolindian assemblage in the uppermost part of the Angullong Tuff and referred the fauna of *Climacograptus supernus*, *C. latus*, *C. normalis* and *Dicellograptus ornatus ornatus* to the *D. anceps* Zone. Jenkins (1978) has also noted that the horizon lies beneath the top of the Angullong Tuff, so that volcanic activity may have continued somewhat beyond the end of *anceps* Zone time. These tuffs are succeeded disconformably by clastics and limestones of the Cadia Group, the basal part being judged by Jenkins to be about the level of the *C. vesiculosus* Zone. This implies a break of possibly two graptolite zones of the latest Ordovician and one of the earliest Silurian.

4. *East of Goulburn*. Sherwin (*in* Pickett 1982) has noted that while the Early Silurian shales of the Jerrara Beds east of Goulburn 'are closely associated with a great thickness of Late Ordovician strata of similar rock kinds, and because of structural uncertainties and known faults in this belt it is not known if sedimentation was continuous from Late Ordovician to Silurian times or not'. Graptolite assemblages of Bolindian and middle–late Llandovery ages have been recorded from many localities, and in one road section on the Hume Highway, a tightly folded succession of shales exhibits both Bolindian assemblages and Llandovery assemblages ranging from the *M. cyphus* to *M. convolutus* Zones (Creaser 1973). However, again there appears to be a significant break (or barren interval) representing the latest Ordovician (two zones) and the earliest Silurian (two zones).

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